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THE GEOLOGICAL STRUCTURE OF TSELIUTSIN, SZECHUAN, THE WORLD'S OLDEST BORE FIELD

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CONTENTS.

PREFACE

The observations of this paper have been rapidly made from October 2 to October 12 of 1929, as a part of the writer's first voyage to Szechuan, executed under the auspices of Sunyatsen University, Canton, and of the Geological Survey of Kwangtung and Kwangsi.

The route followed was from Kiatingfu-Wutungtshou on the Min-ho towards east, over Tsangshantshou and Yunghsien to Tseliutsin, with a rapid return to the lower Min and the Yangtse at Süifu.

The weather was predominantly bad, and the time already so much advanced, that the work could not be carried through as completely as was anticipated.

The map given here as (Pl. I) thus remained incomplete for the region of Kungtsin. It however covers the more important north-eastern district, with the culmination of the anticline.

The writer is much indebted to Dr. and Mrs. Smith-Ader of Tseliutsin for their kind reception in the pretty house of their Mission.

Mr. Chang Min-shao, Assistant of the Geological Department of Sunyatsen University, Canton, has collected with difficulty some data of drilling records. Although only scant precise information was obtainable within the short time of our visit, it seems to be sufficient for clearing up the main stratigraphical succession at the depth, if correlated with the surface-observations of the surroundings.

No records of the perforated formations seem to have been collected by the offices of the salt commissioners. Frequently, even no books were kept by the drillers. The only way to obtain some data was to go to such wells where drilling was still carried on, and to note the verbal data obtained from the drillers. They usually only knew approximately the depths of coal seams, salt and gas or oil, if such were encountered.

The study of the drilling samples, on the other hand, is unreliable, since the holes, apart from 100-200 feet, are not cased. Thus material from above may be scratched off by the bit.

Through the kindness of the Salt Commissioner of Tseliutsin, two maps (Tzeliuching and Kungching Salt Works, 1:10,000), with 25-meter contour lines, were obtained, from which, with a few corrections, the adjoining map (Pl. I) has been reduced. On the original, practically all the bores are located.

At Tseliutsin, I had the great chance to meet the excellent geologist, Mr. Y. T. Chao of the Geological Survey of Peking, and to make some mutual excursions with him, especially to Tawenpao. His sudden death caused by murder at Tshaotung, Yunnan, a month later, is a disaster for China and remains a deep sorrow to myself, after having felt a friendly relationship with him since the first day of our acquaintance.

THE GEOLOGICAL STRUCTURE OF TSELIUTSIN, SZECHUAN, THE WORLD'S OLDEST BORE FIELD

WITH 2 COLOURED SKETCH-MAPS, 1 PLATE WITH SECTIONS, 6 PLATES OF PHOTOGRAPHS, AND 7 DRAWINGS IN TEXT

BY ARNOLD HEIM

PREVIOUS PUBLICATIONS.

Szechuan is the most populated province of China, and Tseliutsin its greatest mining district.

Several books contain ample information on mining and commerce, even with good photographs,[1] but few papers treat with the geology. F. v. Richthofen did not visit Tseliutsin.

Numerous indications in regard to oil and gas of Szechuan have been collected by Hoefer,[2] chiefly after letters from missionaries and other laymen, which contain the most extraordinary statements. They have enumerated all the formations they knew, but unfortunately just left out those which really exist. Not only stratigraphical divisions were mentioned, like Sinian, Cambrian, Silurian, Carboniferous, Permian, or Tertiary, but even Granite and red Porphyry.

About 15 years ago, the Standard Oil Company dispatched their experts to Tseliutsin, and a detailed topographical and geological map is said to have been worked out, but no publications seem to have been issued.

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[1] C. H. Lin, *The Salt Industry in Szechuan* (Large volume with numerous photographs by Dr. Crawford, written in Chinese only and thus unknown in foreign countries), 1919. Crawford, Wallace, "The Salt Industry of Tzeliutsing," *The China Journal of Science and Arts,* in 4 articles with photographs, Vol. IV-V, 1926.

[2] H. Hoefer, in Engler-Hoefer, Das Erdoel, Leipzig, 1909, p. 476.

In the year 1917, the Tokyo Geographical Society, Tokyo, issued an Atlas with text, containing 9 sheets in 1:200.000 of the Red Basin of Szechuan, each topographic and geologic. The surveying of the rivers have been very useful, while the pretty looking contour lines and the geology are unreliable. The Anticline of Tseliutsin however is indicated on the right place in regard to the local river.

Finally, in his *Mineral Resources of China,* the Director of the Geological Survey of Peking, Dr. W. H. Wong,[1] has published the valuable results of the Dutch Mining Engineer Louderbek, with a small geological map in black, a stratigraphic and a tectonic section. The text is in Chinese only and thus has remained unknown to foreigners. An abstract in English, however, was presented by Chu-tingoo.[2]

Stratigraphy of Outcropping Formations

Red Beds (Kweitchou Series),[3] Cretacic.

At Tseliutsin and all around over more than 15 km., only Red Beds are seen at the surface. Their thickness, as much as left from erosion, is over 2000 meters. On the axes of Tseliutsin Anticline, however, the underlying Jurassic comes very close to the surface (Figs. 1-3).

The Red Beds can be subdivided into 3 main series, from above:

3. Upper Red Beds or Kiating Series.
2. Middle Red Beds or Tshungking Series.
1. Lower Red Beds or Tseliutsin Series.

They will be treated separately as follows:

Upper Red Beds or Kiating Series.

This series is characterized by soft massive *brick-red* sandstone with frequent diagonal bedding. It usually forms prominent escarp-

[1] W. H. Wong, *Memoirs of the Geological Survey of China,* Ser. B., No. 1, July, 1919.
[2] Chu-tingoo, *Bulletin of the American Association of Petroleum Geologists,* Vol. VIII, D. No. 2, March-April, 1924.
[3] As defined by J. S. Lee, "Geology of the Gorge District," *B. G. S. China,* p. 379, 1924.

ments above the Tshungking Series, in the shape of tables belonging to wide synclines. This is the case all over the western part of the Red Basin along the Yangtse and the Min-ho. At Kiatingfu, the walls with the celebrated caves of the aborigines are excavated into this brick-red sandstone. On the trail from Tseliutsin southward to Süifu, it is crossed in the form of wide synclinal plateaus (Pl. II). On the syncline of Tatieao is located the famous temple Sanhoasan.

At 8 km. N.W. of Süifu, the great plateau of the brick-red sandstone is cut off abruptly by the Min River. Below the wall of the Kiating sandstone which reaches 200 meters above the river follows the purple-coloured clay and sandstone of the Middle Red Beds, with the same gentle dip of 5-7° to north. (Pl. II and Pl. IX, Fig. 3).

The total thickness, as much as left from erosion, is estimated at about 500-600 meters at the syncline of Tatieao. The lower part (70-100 m.) is a more compact sandstone, while the upper part is more stratified and more argillaceous.

No fossils as yet have been found in the Kiating Series. The author has regarded it as a desert formation.[1]

Middle Red Beds or Tshungking Series.

In the region of Tseliutsin, this series covers a very large surface all around the Tseliutsin Limestone which the author takes as the top of the Lower Red Beds. The general colour in the nature is purple to brown-madder, which distinguishes this series already at a distance from the brick-red Kiating sandstone.

At Tseliutsin, only a minimum *thickness* can be estimated, namely about 1000 meters.

More closely the thickness was obtained by systematic drawing and measuring of the strata along the Min-ho N.W. of Süifu, where a thickness resulted of about 1800 meters (Pl. IX, Fig. 3).

[1] Arnold Heim, "Omeishan," *Bulletin of the Geological Society of China,* Vol. IX, No. 1, 1930.

No *fossils* yet have been found in the Tshungking Series, except impressions of pelecypods, probably of a small Unio or Cyrena, encountered on the road in construction which crosses the anticlinal range S.E. of Tshöngtu (Chengtu). The place is about 2 km. N.W. of Tsatien, the terminus of the motor car road. The stratigraphic position apparently is the lower part of the middle Red Beds.

The Tshungking series is chiefly made of purple more or less sandy clay shales with interbedded sandstones which locally are conglomeratic.

The name is chosen after the large city of Tshungking on the Yangtse, which is built up on a syncline of the middle Red Beds.[1]

The succession of the Tshungking series is excellently exposed on the left bank of the Min-ho at its confluence into the Yangtse just opposite the city of Kiatingfu. The tectonical position is shown in Pl. IX, Fig. 3, while more details of Süifu especially are shown in Fig. 1.

[1] The stratigraphical series of Tshungking (Chungking) will be described in a later paper.

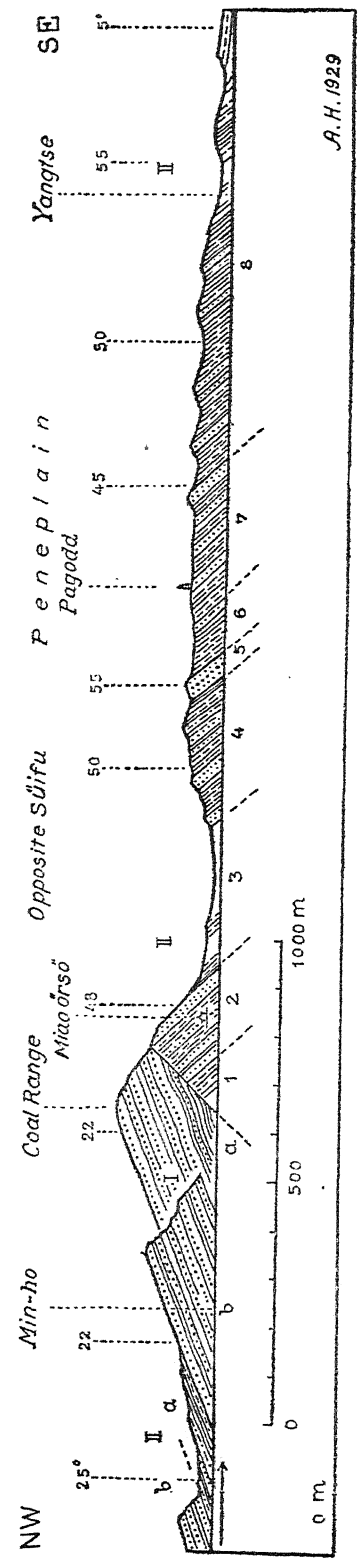

Fig. 1. Exposures on the left side of Min-ho, opposite Süifu.
I. Coal Bearing Formation, Jurassic. *a.* Lower. *b.* Upper.
II. Red Beds, Cretacic. *a.* Lower Red Beds. *b.* Middle Red Beds (1-8).

The middle Red Beds on Tshungking Series at Süifu may be described briefly as follows, with the numbers of Fig. 1:

1. Purple clay shale.
2. 100-120 m. Sandstone and red clay shale (Miao örsö).
3. 200-250 m. apparently purple clay predominant, washed out in form of a longitudinal side valley.
4. 200-250 m. chiefly more or less calcareous variegated clay shale (purple, violet, green, occasionally brick-red), containing red, nodulous, calcareous layers, interbedded with some prominent layers of sandstone.
5. 30-40 m. well defined gray sandstone with a thin conglomeratic layer, interbedded with violet clay of 10-50 cm. each layer.
6. 60-80 m. purple clay shale and marl predominant, in the upper part interbedded with purplish sandstone.
7. 200 m. purple clay shale with layers of sandstone.
8. 600-700 m. purple clay shale predominant, with layers of sandstone, upper part forming blood-red hills.

Lower Red Beds or Tseliutsin Series.

This is the series of which the nucleus of the anticline of Tseliutsin is formed, covering a surface of about 20 square kilometers.

It is nicely subdivided into three parts, from above (see sketch-map, Pl. I):

Lower Red Beds or Tseliutsin Series, 200 m.

3. Tseliutsin Limestone 20-30 m. (Upper Tseliutsin Series).
2. Tseliutsin Red Beds 90-100 m. (Middle Tseliutsin Series).
1. Tungyüe Limestone (Lower Limestone) and Basal Red Beds 60-90 m. (Lower Tseliutsin Series).

A nearly complete section is presented along the Yenho at the city of Tseliutsin, on the steep S.E.-wing of the anticline. (Fig. 2):

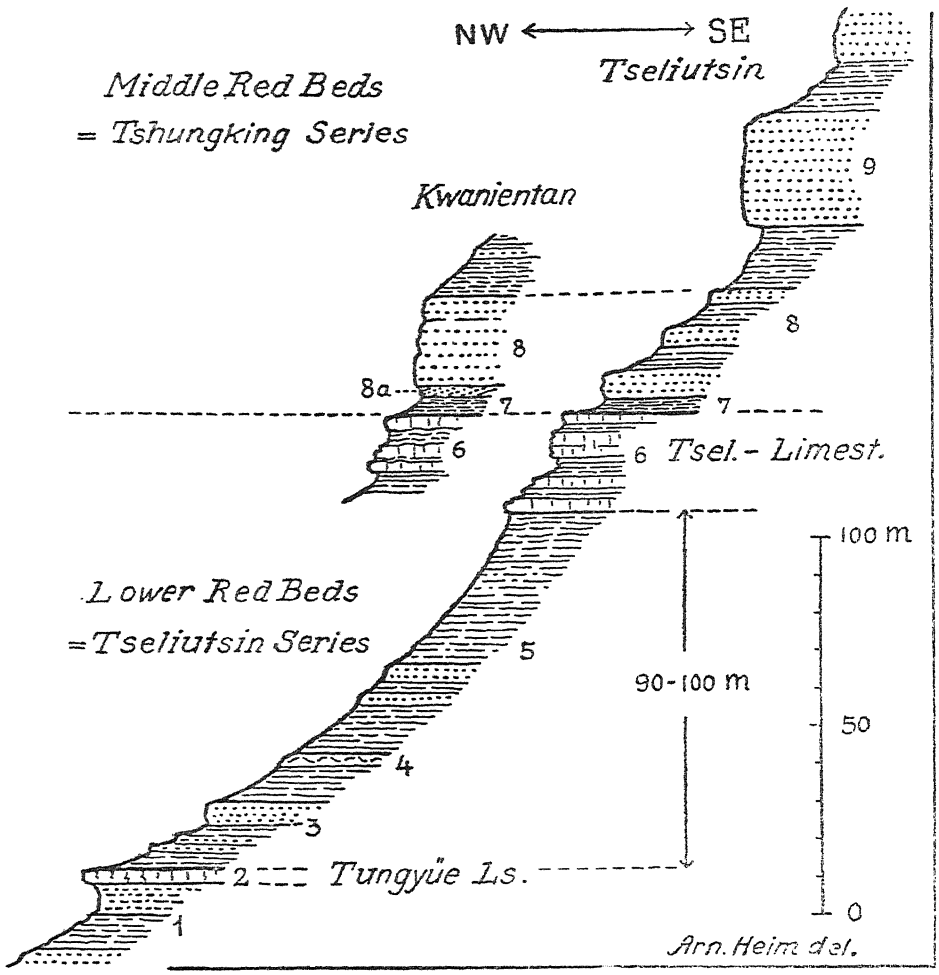

Fig. 2. Stratigraphic succession of the Lower Red Beds at Tseliutsin.

The succession in detail with the numbers of Fig. 2 is as follows, from below.

1. Red clay-shale and marl with sandstone layers, on the top 6-8 m. of yellowish to greenish, slightly calcareous and fine-grained sandstone. Only 20-40 meters of this series are exposed where the anticline passes the Yenho, N.W. of the town of Tseliutsin (Pl. I).

2. 3 m. Tungyüe Limestone. Nodular, hard sandy limestone. The name is chosen from Tungyüe-miao on the culminating part of the anticline.

Being the hardest layer of the whole series, it nearly everywhere forms a small edge in the slope (Fig. 2). Irregular layers of greenish hard sandstone are intergrown with the concrete limestone, thus making this bed easily recognizable as a *first class stratigraphical horizon.* It has been followed for more than 3 kilometers along the axes of the anticline on the N.E. side of the river, while on the S.W. side it dips below the surface. It may be found again in the surroundings of Yunghsien, 25 km. W.N.W. of Tseliutsin.

This layer is full of *fresh water fossils.* The best place for collecting is at the foot of the second bridge on the west side of the town of Tseliutsin, opposite the wooden Pagoda (Phot. 2, Pl. III), where especially a large Unio was found.[1]

3-5:90-100 m. chiefly red clay shale and marls with inter-bedded sandstone. No. 3: layer of yellow sandstone, about 7 meters. No. 4 is a peculiar gray to greenish or pinkish marly *breccia,* made of fragments of 1-3 mm. of marly limestone bedded between variegated marl. Outcrop on S.E. side of Yen River S. of e of the word Tseliutsin on the sketch-map (Pl. I).

6. 20-30 m. Tseliutsin Limestone (Upper Limestone). This name is introduced by Louderbek through Wong, as applied to the limestone which passes along the southeast side of the town, in the shape of the S.E. limb of Tseliutsin Anticline (Pl. IX, Fig. 2, Pl. IV, Fig. 1).

7. 3-15 m. Purple shale, sharply limited, at Tseliutsin Hangshangwe 3 m., in the N.W. at Kwanientan 4-5 m., in the W. at Kungtsin (Fig. 3) 10-15 m.

8. Yellowish sandstone, at Hangshangwe 30-35 m. with clay-shale intercalations, at Kungtsin and Kwanientan more compact (Fig. 3).

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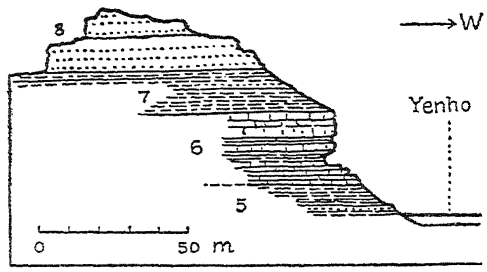
[1] I showed this place to Mr. Y. T. Chao and Mr. Huang, who have taken care of collecting fossils, while I profited of the time of studying the tectonics. It was thought that we would publish the results mutually.

From Kwanientan, a layer of 2 m. at the base (8a) yet is to be mentioned. It is of special interest as a calcareous *breccia,* containing hard pebbles of black silicified wood. This layer shows oblique stratification in its middle part, but is sharply limited as a whole. The sandstone overlying the Tseliutsin Limestone is well marked in the landscape by its walls of yellowish weathering surface, not only at Tseliutsin-Kungtsin, but also further west at Yunghsien (towns and temples on top of rocks) and at Tshukentan on the Mingho.

9. 30 m. Compact sandstone, soft, greenish, sharply limited (N. side of hill 525). Further up constant repetition of red clays and sandstones.

Fig. 3 Top of Lower, and Base of Middle Red Beds, Naidjatan, W of Kungtsin.
No. 5-8 corresponding to Fig. 2, and text.



The best stratigraphical horizon of the Lower Red Beds is the *Tseliutsin Limestone.*

At Tseliutsin, it forms the hills all around the brachy-anticline. It it already known from the Salt Bore Field Tshukentan-Wutungtshou on the Min River, and has been found by the writer again on both sides of the anticline between Yunghsien and Tsangshantshou (half way Tseliutsin-Kiating, Fig. 5).

It thus extends in a E-W direction at least over 65 km. At Tseliutsin, this limestone is cut across by the Yen River and is well exposed, with a dip of 45° to S. 20° E. at Hangshangwe (temple near house of Salt Commissioner, Pl. IV, Fig. 1).

The thickness is about 25 meters. It is not a uniform body, but consists of gray or white to pinkish beds of limestone of 0, 5-2, 5 meters each, with intercalations of gray, yellow, purple and green marls. The limestones as well as the marls, especially in the upper part, are full of small shells of Pelecypods and plant fragments, both, however, of very bad preservation.

The limestone is dense and partly nodular, apparently a *fresh water precipitate.*

On the opposite side of the anticline, at the rocky narrow of Kwanientan, the Tseliutsin Limestone seems to be only about 15 meters thick. The single beds are reduced, with about 75% of intercalated violet marls.

In both places the upper limit of the Tseliutsin Limestone is very sharp, and presents an accurate subdivision between the Lower (Tseliutsin Series) and the Middle (Tshungking-Series) of the Red Beds. The lower limit is less distinct.

Coal Bearing Sandstone (Hsiangchi-Series), Jurassic.

This formation does not quite reach the surface at Tseliutsin.

Region of Yung-Hsien.

The large anticline which accompanies the Tseliutsin Anticline to the N.W. brings the coal-bearing sandstone to the surface over a long distance. From far away it is recognized as a dark mountain range with pine trees.[1]

From numerous places coal is mined, as for instance N. of Tja-shön some 20 km. N.N.W. of Tseliutsin, N. of Yung-hsien (Saen-tshing-tien), and S. of Tshangshantshou.

The great coal-bearing threshold of Yung-hsien is mantled with the Tseliutsin Series, which on the trail W. of this city dips 10° to S. 30° E., and is of the same type as at Tseliutsin itself: 150-200 meters of red clays and sandstones, covered with the Tseliutsin Limestone of about 20 meters. Here again, the Middle Red Beds commence with a layer of red clay, which is capped by massive yellowish sandstone.

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[1] The Tokyo Atlas, sheet No. 8, 1: 200,000, does not show this anticline (colour= "Upper Red Formation"). An anticline is drawn W. of Tshangshantshou in a rather synclinal position.

It is the latter on which, with a general dip of around 5° to S., is situated the huge golden Buddha Head of Yung-hsien (Lung-shan).

Region of Süifu (Hsütshoufu).

The coal bearing Jurassic again appears at the surface 65 km. S. of Tseliutsin, at Süifu, *thrust-faulted over the Middle Red Beds* (Pl. IX, Fig. 3, and Fig. 1).[1] The basis of the Jurassic is not exposed at Süifu. The minimum thickness is about 250 meters.

At the lower part, on the N. bank of the Min-ho across Süifu is exposed a series of dark sandy clay with sandstone layers, containing fossil plants and thin coal seams. The thickness of this lower subdivision may be guessed at 70 meters. Above, it follows the more compact sandstone of 150-200 meters, which forms a mountain range rising to about 300 meters above the river (Coal Range in Fig. 1). Coal is said to be mined along this range towards N.E.

The stratigraphic importance of the section of Süifu is presented by its *undisturbed relation with the Red Beds.*

With a regular dip of 22° to N. 30-45° W. the following succession above the main coal-bearing sandstone has been noted, following the S. bank of the Min-ho above the city of Süifu:

(*a*) 5 m. sandstone with red and green clay shale.
(*b*) 20 m. fine grained green thin-bedded sandstone with red clay layers.
(*c*) 50 m. red clay predominant.
(*d*) 5 m. marl and red clay shale, with nodulous parts of sandy limestone containing traces of shells.
(*e*) 150-200 m. chiefly red clay, partly exposed.
(*f*) 200 + m. chiefly sandstone in thick prominent layers.

No. (*d*) of this succession may correspond to the Tungyüe Limestone, thus (*a-d*) = Lower Red Beds.

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[1] The Tokyo Atlas shows a normal upright anticline.

The most important observation is not only the *perfect conformity* of the Coal Bearing Series with the Red Beds, but the *continuity of*

Stratigraphical Data from Drilling

A very valuable stratigraphical section obtained from drilling is given by Dr. Wong after Louderbek. The following divisions are distinguished below the Tseliutsin limestone:

(*a*) 600 ft. Red and gray shists with some gas and yellow brine.

(*b*) 1,500-2,000 ft. Sandstone with coal beds on the top and in the middle part, yielding yellow brine, gas and petroleum in the lower part.

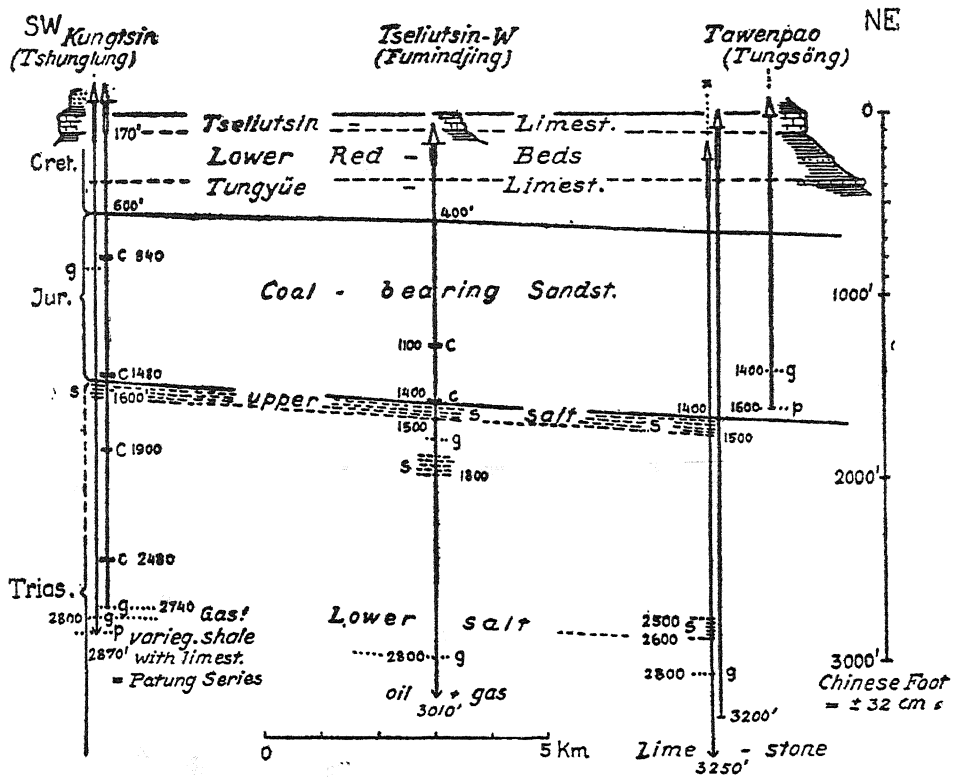


Fig. 4. Essay of correlation from Bores.
c coal, *s* salt (brine), *g* gas, *p* petroleum.

(*c*) 1,500-2,000 ft. Limestone and variegated marls (?) with black brine, gas and petroleum, especially at the base.

(*d*) Big body of Red Shists.

Independently from this conception, although based only on a few half reliable data gathered verbally within a few days, the writer came to the conclusion as summarised in the sketch (Fig. 4).

If we take the lower boundary of the coal bearing sandstone (Jurassic) at the base of the 1,400 ft. coal seam the scheme given by Louderbek coincides very well with our Fig. 4. This coincidence strengthens the chronological interpretation of this paper.

The reasons to take the limit of the coal bearing formation below 1,400 ft. coal are as follows:

(1) According to my measurements on the surface the coal bearing formation is in no place thicker than 400-500 m. in the surrounding country.

Examples: below Hochow on the Kialingkiang 400, Tshungking 350-400, Cat Gorge above Tshungking 480, Omeishan 250-300 meters.

(2) The coal bearing sandstone is not of the character of a salt bearing formation.

(3) The triassic series in the surroundings of Tseliutsin terminates with marls, not with limestone.

(4) If the above changement for subdivision is made, the section of Louderbek corresponds nicely with the surface observations of the triassic series, which from above is made of (*c*) yellowish marls, (*b*) limestone which towards the base becomes interbedded with variegated marls, (*a*) purple marls and clay shales (Patung Series).

In conclusion, our interpretation for the Bore field of Tseliutsin is as follows:

Below the Red Beds follows the coal bearing sandstone series (Hsiangchi series) which is generally regarded as *Jurassic,* with a thickness of 300-400 meters.

What is below the 1,400-1,500 ft. coal seam belongs chiefly to the Triassic, which yields the *primary deposits of salt and oil,* as well as the greatest part of the gas.

The triassic series in no place seems to have been traversed by drilling.

The occurrence of coal in the Triassic series is no objection to this conception, coal seams being known also in the Patung Series in the Yangtse District below Wanhsien.

Tectonical Structure of Tseliutsin Anticline.

Tseliutsin is situated on a beautiful *Brachy-Anticline*. The axes culminates on the S.W. side of Tawenpao, where the Tungyüe Limestone reaches nearly the contour of 550 meters of the Salt District Map, and is about 50 meters above the river (Pl. I).

The direction of the *axes* is E. 30° N. apart from the Yen River. In the opposite direction, as already indicated by Louderbek-Wong, the axes seems to turn from S.W. to W.

The *central part* of the anticline is perfectly flat, with a nearly 1,5 km. width of strata dipping less than 5 degrees. (Pl. IX, Figs. 1-2).

About 1 km. N.E. of Tawenpao, a slight *pitch* of 1-3° is noticed, and even 3-4 km. away from the culmination the pitch remains around 2-3° only towards E. 30° N.

In the opposite direction, a distinct pitch can be already noticed along the Yen-ho N.W. of the town of Tseliutsin, where the difference of height of the Tungyüe horizon on both sides is obvious, and corresponds to 3-5° towards W. 30° S. West of Kungtsin the average pitch seems to be less than 5°.

At the same time, the anticline flattens out at both ends.

The *N.W. limb* is the longer and the more gentle. The section after Louderbek, which shows a steeper N.W. limb is incorrect, but nearly corresponds with the nature if N.W.-S.E. are interchanged. Only locally, dips up to 15° have been found, namely, in the lower part

of the Middle Red Beds at Kwanientan and Kaotung. Thereof, for several kilometers, the dip is regular, with angles of 10-8° towards N.N.W. The landscape is governed by the sandstones which look out of the purple clay. Then the dip gradually diminishes and reaches zero, according to verbal communication by Mr. Y. T. Chao, at the town of Tjashön.

The *N.W. limb* of Tseliutsin Anticline thus would have a width of about 12 km., and a depth of about 1,3 km. (Pl. IX).

The *S.E. limb* is characterized by a *short piece of steep inclination.* The Tseliutsin Limestone on the river dips 45° to S. 25° E., the overlying sandstone even 50° to 55°. But these steep dipping strata only cover a narrow zone on the S.E. side of the town of Tseliutsin, of 200-300 meters, on both sides of which the inclinations rapidly diminish, as shown on the maps and sections.

Also the S.E. limb as a whole is *shorter* than the N.W. limb. On the trail from Tseliutsin to Süifu, immediately S.W. of the small town of Sudjao, the gentle S.S.E. dip is at once replaced by dips of 6-10° towards W. and W.N.W. On the rapid trip it could not be determined if this change is caused simply by a syncline with a pitch to S.W., or if a fault is also present.

In either case, the width of the S.E. limb of Tseliutsin anticline is around 7-8 km., while its depth over 1,000 meters.

The syncline on both sides of Tseliutsin Anticline thus are of a similar depth and both anticlinal wings of about equal importance in regard to the collecting of oil and gas.

Tectonical Structure of Surroundings.

Region West of Tseliutsin.

At Kiatingfu, the upper Red Beds (Kiating Series) form cliffs of soft brick-red sandstone with cross-bedding, in a horizontal, synclinal position. Going south along the Min River, the Tshungking series comes to the surface owing to a gentle rising of the strata until Tshukentan-Wutungtshao, the eastern-most salt borefield of Szechuan.

There, the Tseliutsin Limestone reaches the surface, as already described by Wong, with a general dip of 5-7° towards N.N.W.

On account of rain and fog, the writer did not visit the south side of the Tshukentan salt field. According to Louderbek-Wong, it is situated on a very gentle *anticline,* which can be followed towards E.N.E. as far as Wei-yüan-hsien, 20 km. N. of Tseliutsin, *i.e.,* on a distance of 85 km.

If this really is the same anticline all along, it must widen and also rise considerably towards E., as much as 500 meters at least. Indeed, between Tshangshantshao and Yunghsien the trail passes over a wide mountain range already seen from a long distance with its dark pine trees on the crests. The excellent map of Yunnan by Davies 1.1,267,000 does not show this mountain range in the Red Basin. (Fig. 5).

N.W. of Tshangshantshou, the Tseliutsin Limestone is widely exposed. S.E. of Tshangshan River, thick-bedded sandstone at once rises out of the valley with a dip of 20-25° towards N.N.W. Possibly, this dip is accompanied with a longitudinal flexure. About 5 km. S.S.W. of the town, a large coal mine is worked. The coal is rich in FeS_2, black, and of the aspect of the ordinary Jurassic coal of Szechuan.

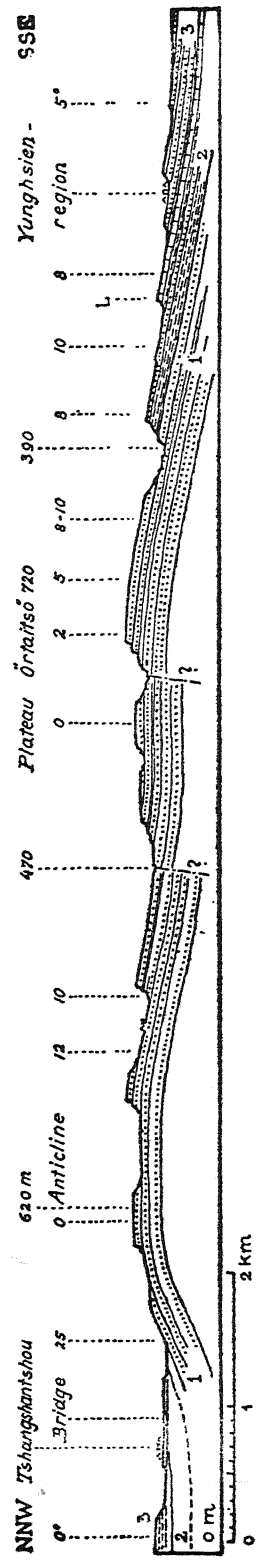


Fig. 5. Sketch across the Coal-Range of Yung-Hsien

1. Coal Bearing Sandstone (Jurassic).
2. Tseliutsin Series and 3 Tshungking Series of Red Beds (Cretacic).

Several sub-ranges of yellow sandstone are crossed. Perhaps, they are longitudinally faulted as shown in Fig. 5. On the S. side of the anticlinal range, the Red Beds again are conserved, with the Tseliutsin Limestone dipping regularly 8-10° to S. 30° E.

Region South of Tseliutsin.

The trail from Tseliutsin towards S. to Süifu, 220 *li,* travelled rapidly in two days, has shown the following structural features (Pl. II).

1. *Anticline of Pähua-tshang.* Direction of axes around N. 30° E., limbs very regular, with dips up to 10°, apex flat, on both limbs 50-100 m. high cliffs of brick-red sandstone, seen from long distance and joining S.W. of Pähua, according to a 3-5° pitch of the anticline (Fig. 6).

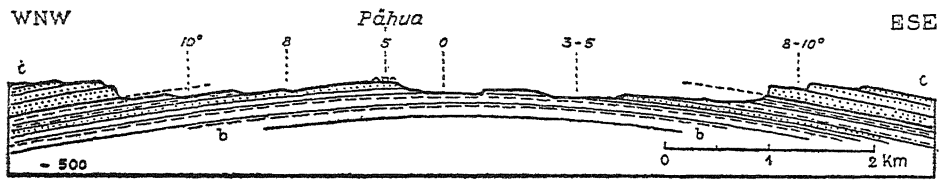


Fig. 6. Anticline of Pähua-tshang.

b. Middle Red Beds, Tshungking Series.
c. Upper Red Beds, Kiating Series.

2. *Syncline of Tatieao.* Direction of axes E.N.E. N.N.W. limb gentle and long, S.S.E. limb with dips up to 25-30° over 200-300 meters. This shows that the *folding is younger than the Upper Red Bed Series.*

3. *Anticline of Takio.* A second beautiful anticlinal frame is passed south of Takio between Tatieao and Yentshatshang. It is eroded in form of a 100-150 m. deep valley cut out into the purple clays of the Tshungking Series. The brick-red walls are closed towards W., with a diameter of the circus of 2-3 km. This Kilauea—like shape again is caused by anticlinal pitch. It is however less than 2° to W.S.W.

Region of Süifu (Pl. IX, Fig. 3).

After passing a shallow syncline on the Plateau of Yentshatshang, the Red Beds turn up again to form a regular upright anticline

at Süifu, according to the Japanese Atlas 1917. But this is not the case.

The Coal bearing sandstone is thrusted with a right angle against the Red Beds of the southern limb. The thrust plane, was not found exactly exposed in the lower part of the coal range, but there were so little of debris between the two oppositely dipping series, that no doubt remains about the above conception. The basal Jurassic, formed of dark clay with sandstone layers, shows a dip, behind the factory, of 30-35° to N.N.W., while the main sandstone above it dips regularly 20-25°.

Apparently, the Süifu Range thus is originated by a *longitudinal fault on the apex of the anticline* ("Scheitelbruch") along which the northwestern wing has slipped over the southeastern one.

Just below the confluence of the Min into the Yangtse, the next *syncline* is visible. As a whole it is nearly symmetrical again, striking E.N.E. to N.E., and of a great depth of about 2 km.

According to the Japanese Atlas, the S.E. side of the Yangtse at Süifu is made of another anticline of sandstone crossing the stream with a width of 5 km. Kobayashi however has confounded again the coal-bearing Jurassic with the Red Bed sandstones of Cretacic. As seen from the steamship, the anticline forming the Nan Kwong side-gorge pitches 5-7° towards N.E., so that the Jurassic nucleus does not reach the Yangtse. Indeed, the left bank of the stream shows a beautiful anticlinal arch, the sandstones of which however belong to the lower part of the middle Red Beds or Tshungking series. (Pl. II and Fig. 7).

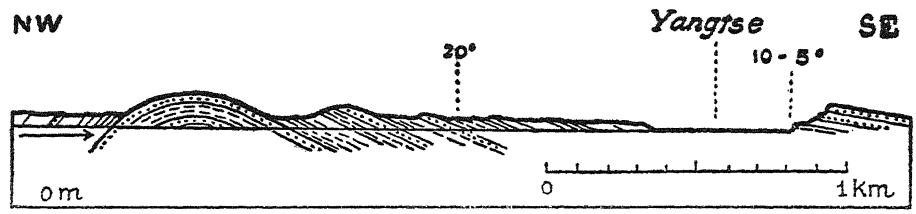


Fig. 7. Pitching Nan Kwong-Anticline.

8 km. E.N.E. of Süifu. All Middle Red Beds (Tshungking Series).

Further down, until Tshiangan, the Yangtse crosses 2 more anticlines of lesser depth and angles, and with synclinal platforms of brick-red Kiating Sandstone between. The anticline above Tshiangan shows a nice pitch towards S.W.

Towards Tshungking, numerous more important anticlines follow, showing not only Red Beds and coal bearing sandstone at the surface, but the big series of Triassic, and exceptionally even a nucleus of Permian limestone. They will be described in detail in a separate paper.

Morphological Features.

As usual in the Red Basin of Szechuan, the folds of the Red Beds are *incompletely peneplained*. The hills on the crest of the anticlines are not, or not much, higher than on the limbs, the general level of the peneplain being 80-120 meters above the rivers.

The height of Yenho at Tseliutsin on the salt district maps is taken as about 490 meters, while it is considered by the writer as about 350. The highest hill on Tseliutsin Anticline is situated W.S.W. of Tseliutsin, and rises 150 meters above the river. It is made of the basal sandstone of the Tshungking series, and belongs to the S. limb. (Pl. I). Hills with steep slopes towards the anticline of 100-150 meters above the river are even found farther away in the S.E. limb, made of sandstone beds within the Middle Red Beds or Tshungking Series (Pl. IX, Fig. 1.).

The level of 125 meters above the river is found all around the culminating part, which itself is eroded down to the Tungyüe Limestone at 50 meters above the river (Pl. IX).

Taken as a whole, the flat synclines which surround Tseliutsin however are more lowered and more levelled than the anticlinal regions. Compared with the tectonical amplitudes of over 1 km., a surface amplitude of 120-175 meters is very small. All this difference is due to the levelling effect of erosion (Pl. IX, Fig. 1).

Going to the south, we have found that the anticline of Pähua again is peneplained to about 100 meters above the level of the Yenho,

the surface of the apex being not higher than that of the limbs (Fig. 6). And even over the syncline which follows towards south, the platform of 100 meters persists notwithstanding the erection up to 30° of the uppermost Red Beds (Tatieao).

On the Min-ho, above Süifu, the average surface of the synclinal platform is about 150 meters above the deeply eroded river valley, the highest points reaching about 200 meters above the Min (Pl. IX, Fig. 3).

On the upper part of Min-ho, west of Tseliutsin, the general levelling of the surface of the Red Beds is even more equalized. The anticlinal sandstones covering the Tseliutsin Limestone at Wutungtshao rise scarcely higher than the hills of Kiating-fu (70-100 m. above the river). (See Phot. in Arn. Heim, Omeishan, Bulletin of the Geological Society of China, Vol. IX, No. 1, 1930).

If thus the amplitude of surface elevation within the Red Beds is limited, the *larger anticlines,* however, with their nucleus of coal-bearing sandstone, are *overtopped by the Red Beds.* Thus, the Range between Yung-hsien and Tshangshantshou reaches 300-400 m. above the Yenho. A similar fact is found at the Coal Range of Süifu, at the Range of the Cat-Gorge, at Tshungking. On the latter the coal bearing sandstone forms two rows of hills belonging to the limbs of the anticline, the triassic limestone of the nucleus being weathered down to a longitudinal valley. Indeed, the Tshungking hills rise as much as 500-550 meters above the Yangtse.

But the writer also has found one anticlinal Red Bed-threshold which does not show the Jurassic nucleus, and still rises high over the peneplain: it is the long range, which borders the Tshöngtu-Plain towards S.E. According to barometric readings, this range, near the pass from Tsatien to Lungtshan-i, reaches about 1,000 meters, 450-500 meters over the Tshöngtu Plain and 600 meters over the To-kiang. The explanation of this abnormal case has already been given in considering this fold as the *youngest orogenetic movement* within the Red Basin. (Arn. Heim, Zeitschrift d. Ges. f. Erdkunde, No. 3-4, p. 124-126, 1930).

The great Chengtu-Plain excepted, the Red Basin of Szechuan is strikingly *poor of quaternary accumulation.*

Typical quaternary *terraces* have been encountered at Omei-hsien (see Arn. Heim, Omeishan, Bulletin of the Geological Society of China, Vol. IX, No. 1, 1930). The lower of those terraces is represented again on the Yen-ho E.S.E. of Tseliutsin, at about 15 meters above the river (Pl. IX, Fig. 2).

The *Red Basin actually is in a condition of predominant erosion,* apparently due to epeirogenetic uplift.

The Salt, Gas and Oil of Tseliutsin Anticline.

On Tseliutsin Anticline, about 4,000 Bores are located, of which about one-tenth are in operation.

Salt.

According to Louderbek, salt resp. brine has been encountered by borings in all stratigraphic divisions:

1. Little yellow brine in the basal Red Beds, about 150 m. below the top of Tseliutsin Limestone (Cretacic).
2. Yellow brine in porous sandstone, interbedded with coal seams, mined in places far away from the axes of the anticline. Content of salt 10-15%.

   Depths below top of Tseliutsin Limestone about 350 and 450 m. (Jurassic in upper part).
3. Black brine, lower level, 700-1,000 m. (Triassic), usually at drilling depths around 3,000 ft. and along the axes of the anticline. Much H_2S, FeS_2, with a content of salt from 10-20, rarely 25%. At Tawenpao, dry rock salt is found.

This lower horizon is the richest, and therefore the bores, exhausted on upper horizons, go down if technically possible. It is the primary triassic horizon, while the higher horizons might be secondary ones,

at least part of them, the brine having migrated under the pressue of the gas.

The statement that this lower horizon is confined to the axes of the anticline possibly has no geological cause, but may derive from the depth which, with the old drilling methods, could not be reached in the limbs.

The results obtained by the authors' party from verbal communication with the drillers are summarized in Fig. 4. As a whole, they seem to correspond with the data of Louderbek. The brine usually rises by itself at the bottom of the whole some tens of meters, until it is bailed. In some places where rock salt is found in the deeper horizon, water is poured into the hole and left there for 7 to 10 days, according to Dr. Crawford.

Gas.

According to Louderbek-Wong, CH_4 is the most important constituent. It is found at 700-800 ft., at 1,800-1,900 and at 2,600 ft. "Gas in large quantities always occurs in porous sandstone overlain by dolomitic limestone, which in turn is overlain by the black brine-bearing strata."

The richest gas fields are situated on, or near, the apex of the anticline, actually not on the culmination, but W.S.W. of it, namely on the W. side of the town of Tseliutsin and on the W. and S.W. of Kungtsin.

During the author's visit, in October, 1929, one well W. of Kungtsin called Tiänlungtsin was said to produce from 2,740 ft. (= 2,665 ft. below top of Tseliutsin Limestone) enough gas for 375 boiling pans, and this since 7 years already. Many wells produce brine and gas at the same time, the brine being bailed from the depth, while the gas is led to the boiling plant.

The neighbour well "Tshunglung," located about 25 meters above the Tseliutsin Limestone produces from 2,800 ft.-2,870 ft. a brine which

rises about 20 meters in the hole every 24 hours. At the same time gas emanates for 24 boiling pans from this depth. The upper gas from 900 ft. is not important.

The biggest gasser, in October 1929, was said to be situated on the anticline near the watershed (Tseliutsin Limestone) between Tseliutsin and Kungtsin.

The main gas horizon is situated at about 3,000 Chinese feet below the top of the Tseliutsin Limestone, and with the main salt horizon unquestionably belongs to the Triassic (Patung Series).

Oil.

According to Höfer, oil during last century was produced by 30-40 wells, which were reduced to 15, with a total output of around 4,000 Liters per day.

After Durand, the highest single production was 1,200-1,500 kg. per day, dropping to 250 in one year.

Louderbek (in Wong) says that the lower sandstone and the dolomitic limestone always contain little oil, especially the basal sandstone of the coal-bearing strata at 2,000-2,200 ft. depth. If this sandstone yet is Jurassic may be questioned. It is situated 1,500-2,000 ft. below the Red Beds. Unfortunately, the section of Louderbek is not drawn in scale. Certainly, the dolomitic limestones are Triassic.

The largest production was obtained from a well drilled at the end of last century on the axes of the anticline. It yielded 3,000 catties, equal to about 1,800 kg. per day.

During the writer's visit in 1929, the production of oil was practically nil. There is no special oil well, the oil being found only swimming on the surface of brine at a few wells.

From the data collected, the following are worth to be mentioned.

PHYSICAL PROPERTIES OF CRUDE OILS FROM TSELIUTSIN IN ANTICLINE

Name of Well	Location	Approximate depth in meters below top of Tseliutsin Limest*	Colour in translucent light	Colour in reflected light	Density (=spec. gravity)	Solidifying point
Tshunglung	3 km. W of Kungtsin	940	light orange	light-green	0,827 at 20°C.	below— 10°C.
Tungtsong	1.5 km. NE of Tawenpao	510	red-brown	dark olive-green	0,890 at 29°C.	— 2°C.
Tungtshang	2 km. NE of Tawenpao	415	dark red-brown	dark olive-green	0,862 at 20°C.	— 8°C.
?	Tawenpao	?	dark red-brown	brownish-black	—	+ 10°C.

* Chinese foot taken as 0,32 meter.

Well "Tshunglung," W. of Kungtsin, located about 25 m. above the top of Tseliutsin Limestone. Oil at 2,870 ft., 40-50 Katties (25 kg.) per day since 11 years, initially 60-120 kg. oil per day coming up with the brine. Also much gas, enough for 24 boiling pans, said to emanate 2-3 feet above the oil. Drilling samples show reddish and green clay shale with fragments of quartzite (Triassic).

Well "Tshungsöng," 1,5 km. N.E. of Tawenpao, on Tseliutsin Limestone and just on the axes of the anticline (T on Map Pl. I), 80 m. above the river. Oil on brine from about 1,600 ft. depth, a few catties per day.

Well "Tungtshang," 1,2 km. N.E. of Tawenpao, on top of Tseliutsin Limestone. Oil 1 catty per day at about 1,300 ft., on brine, with gas for two boiling pans.

The physical properties of the oils gathered from Tseliutsin Anticline are given in the following table. The author is much indebted to Professor Chen-Chung-Nan, Director of the Chemical Department of Sun Yat-sen University, Canton, for the determinations of the densities and of the freezing points.

The samples gathered were of unsufficient quantities for chemical analysis.

It would be a very interesting task for a scientist living at Tseliutsin district to gather all possible oils and to find out how much they differ according to the horizons.

The lower oil at 900-1,000 meters below the top of Tseliutsin limestone is probably a primary oil, while the oils of the Jurassic sandstone may be migrated from below.

Some Words on Drilling and Producing Methods.

Szechuan is known to have produced salt for about 2,000 years. At first brine seepages were found on the River N.E. of Kungtsin. They are said to have been stopped by earthquakes, after which boring was

invented, over a thousand years ago. Since that time the drilling methods have remained practically the same and are still applied as a rule, although modern drilling with steam engines has been introduced this century in some places.

Rock salt was discovered about 40 years ago at Tawenpao on the culmination of the anticline.

The book of Lin gives a full account of drilling methods and tools, but only in Chinese. An excellent shorter description in English was presented by Dr. Crawford, to whom also are due the photographs in Lin's work. Not being at hand to all geologists, a brief account after personal investigation may be welcome here.

The location of the wells is made without any scientific views, and in disregard to the topography, usually according to consultations of "Geomancers."

Most of the productive wells are around 1,000 meters deep. They are cased to a depth of 100-200 ft. with bamboo. This bamboo, with an inner diameter as measured by the writer up to 12 cm. or more and with strong walls of 12 mm. thickness is specially cultivated at Kiang-an (Tshiangan) on the Yangtse, below Süifu (Pl. II). This town is also the centre for all other kind of bamboo work; bamboo ropes for drilling and bailing made of hand-twisted splittings, bamboo-pipe lines, bailers, etc.

In sinking a well, a hole of 1,5 meters in diameter is dug first to 20-30 meters, and then the hole continued for some further depth with a diameter of one foot (Crawford).

Afterwards, a derrick is erected, made of skinned pine poles spliced together with bamboo rope and wedges (Pl. VI, Fig. 1). These huge tripods (to which usually is added a fourth smaller pole) reach the height of a modern standard rig in America (100-120 ft.). On the top is placed a cross beam with a wheel over which is run the bamboo cable.

In some places, a single bamboo band is used for drilling instead of bamboo rope (Tawenpao). Drilling is executed with a walking beam.

On one side of it it fastened the rope with the iron bit. On the other, longer side, 3 or 4 pairs of men step over, crossing each other, forcing at once the beam down by their weight, and letting it loose again. By this movement the bit is raised and dropped about every 2-3 seconds. An advance of drilling may be made of 1 to 3 feet per day. (Pl. VI, Fig. 2).

In some cases a well was drilled for 10 and more years until finished. Thus, a bore on the east side of Tawenpao was in operation for 6 years to make the progress from 2,700-3,250 ft., with a daily progress of 6-15 centimeters only at the time of the writer's visit.

For bailing the brine, a long bamboo pipe with a common suction valve is used.

The bailer is raised by water buffaloes which pull on a huge windlass with a vertical axle, of a diameter of 6-8 meters.

The operation of raising the bailer and letting it down again only needs 15-25 minutes.

The brine is led by gravity, or pumped by buffaloes or men over the hills (Pl. VII) to the boiling plant, where the brine is condensed in large flat iron pans, heated with natural gas or coal. (Pl. VIII, Fig. 2). The solid salt is transported in crude dirty blocks or in a refined condition over hundreds of miles, partly by horses and donkeys, partly by porters, as far as to Yunnan, a distance of 6 weeks of travelling.

Over one million of people in Tseliutsin district are said to be connected with the salt business.

Valuation for Production of Oil.

Tseliutsin Anticline.

Unquestionably, the *tectonical structure* of Tseliutsin Anticline is *ideal for an oil field*. The collecting area is 500 square kilometers at least, possibly 1,000. It ranges with the finest brachy-anticlines of oil countries like Mesopotamia, Wyoming, Burma, Sumatra.

The question thus arises, if the failure in producing paying quantities of oil is due to errors of drilling.

Indeed, if the holes were full of water, the pressure against the oil, at 1,000 meters, would be 100 atmospheres. But this is not the case. The holes usually are filled only with 10-30 meters of brine or even less. Since they are uncased, the oil would flow into the hole if there would be any amount of it.

The only question which remains is: may we expect deeper oil horizons which have not been reached yet.

Louderbek states, that no oil was obtained from the strata below the black brine (lower salt). According to the writer's information, however, the Fumindjing well struck gas with little oil at 3,010 ft., at a level which apparently is below the lower salt (Fig. 4). But it is true that the deepest wells did not give any hope for further oil horizons, nor does this triassic series where it comes to the surface. This is the case at Omeishan on the west, and of the Kialing Kiang on the east side, where big bodies of limestone are underlain by purple or chocolate shale without signs of impregnation or porous rocks for proper storage of oil.

The hopes thus to strike oil in larger quantities with new drilling methods until depths to 1,100 meters are to be cancelled, and the probability of finding paying quantities below this depth are very small.

Surroundings of Tseliutsin.

Similar to Tseliutsin Anticline, brine with little oil or an emulsion of it on the brine is exploited at Tshukentan-Wutungtshao on the Min-ho, without better prospects.

The question however remains open for numerous beautiful other anticlines of the Red Basin.

South of Tseliutsin, we have found the wide and gentle anticline of Pähua (Fig. 6 and Pl. II). It would be worth a special study, since we only know part of it, without having determined its northern end

nor its accompanying synclines. It is quite possible that another salt and gas field would be discovered, although Pähua would require somewhat deeper drilling than Tseliutsin.

The most promising structure for drilling on oil within the region studied by the author is the anticline at *Yenpoa,* 30 km. S.S.E. of Tshungking near the boundary of Kweitshou, with the oil seepage of Meyugo on the axes. A later paper will deal with this and other oil regions of Szechuan.

EXPLANATION OF PLATES.

PLATE I.

The topography is reduced from the salt district map in 1:10,000. Few corrections and additions (Kwanientan) were made. According to this Chinese survey, the Yenho would have an elevation above sea, at Tseliutsin, of about 490 meters, while the present author has found about 350, as controlled by frequent barometric readings. The whole topography thus might have to be considered as about 150 meters lower.

The time was insufficient to complete geological mapping in the region of Kungtsin. Such completion however would not have changed the general structural conceptions.

PLATE II.

TECTONICAL SKETCH-MAP TSELIUTSIN-SÜIFU.

The topographic base is chiefly taken from Davies' Map of Yunnan, 1:1.267.200.

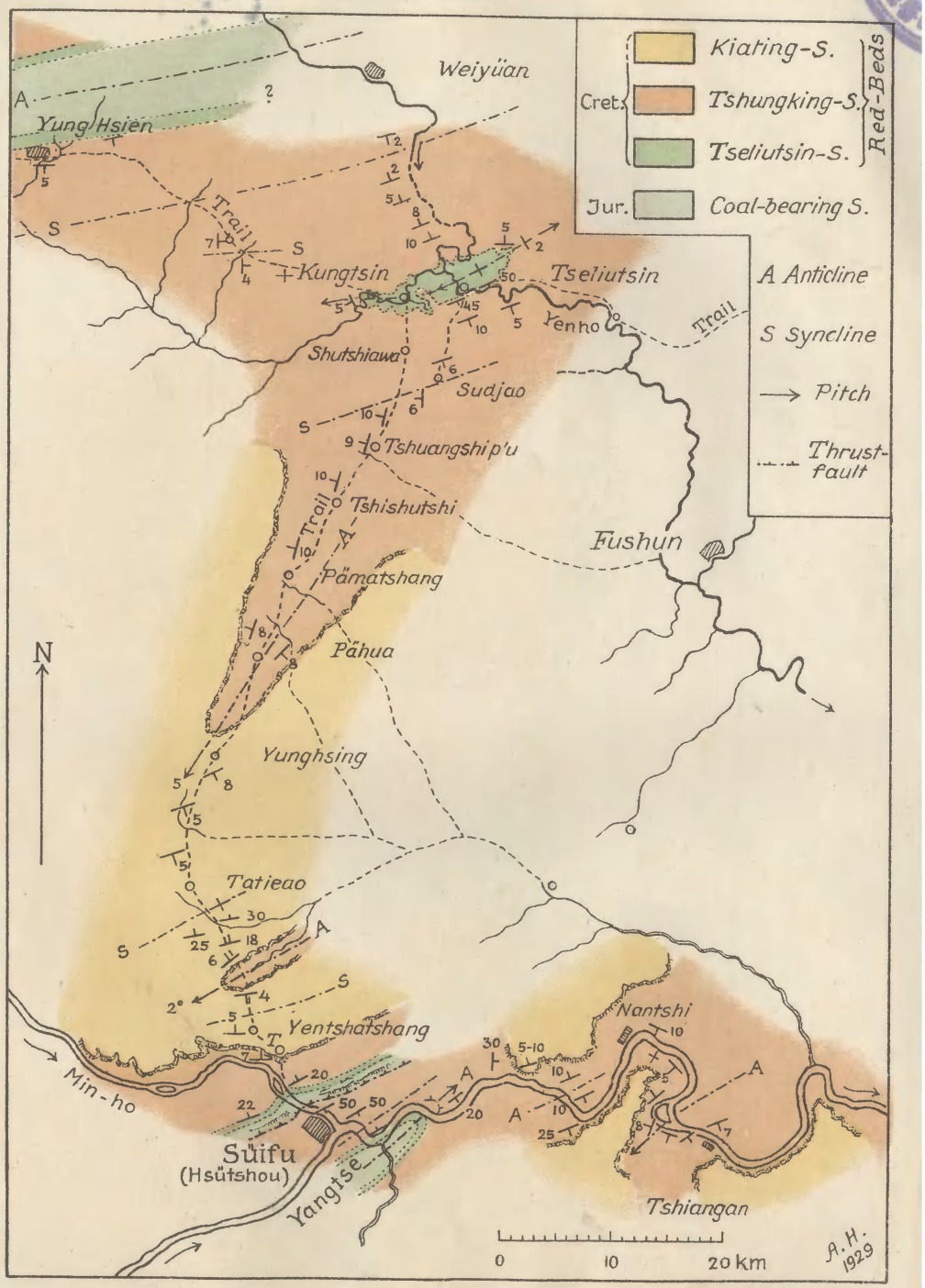
The trail from Tseliutsin to Süifu (220 Li) was to be made in two days, a time too limited for compiling a careful itinerary. The trail thus is given after Davies. Tseliutsin is reduced from Pl. I. The course of the Yangtse and Min has been reduced from the Japanese Atlas 1:200,200.

The N.W. corner of this sketch is purely schematic, the anticline being traced after Louderbek. The author has not visited the region between Yunghsien and Weiyüan.

Pl. II.

Tectonical Sketch-Map Tseliutsin - Süifu

by Arnold Heim



Geological Sketch-Map of Tseliutsin

Low. Cretac.

- Middle Red Beds
- Tseliutsin Limest. (Up. L.s.)
- Tseliutsin Red Beds
- Tungyüe - Limest. (Low. L.s.) and Basal Red Beds
- Anticline
- Pitch of Axes
- Town.
- Position of Strata
- Bores on Salt & Gas
- Culmination
- A — B Direction of Section

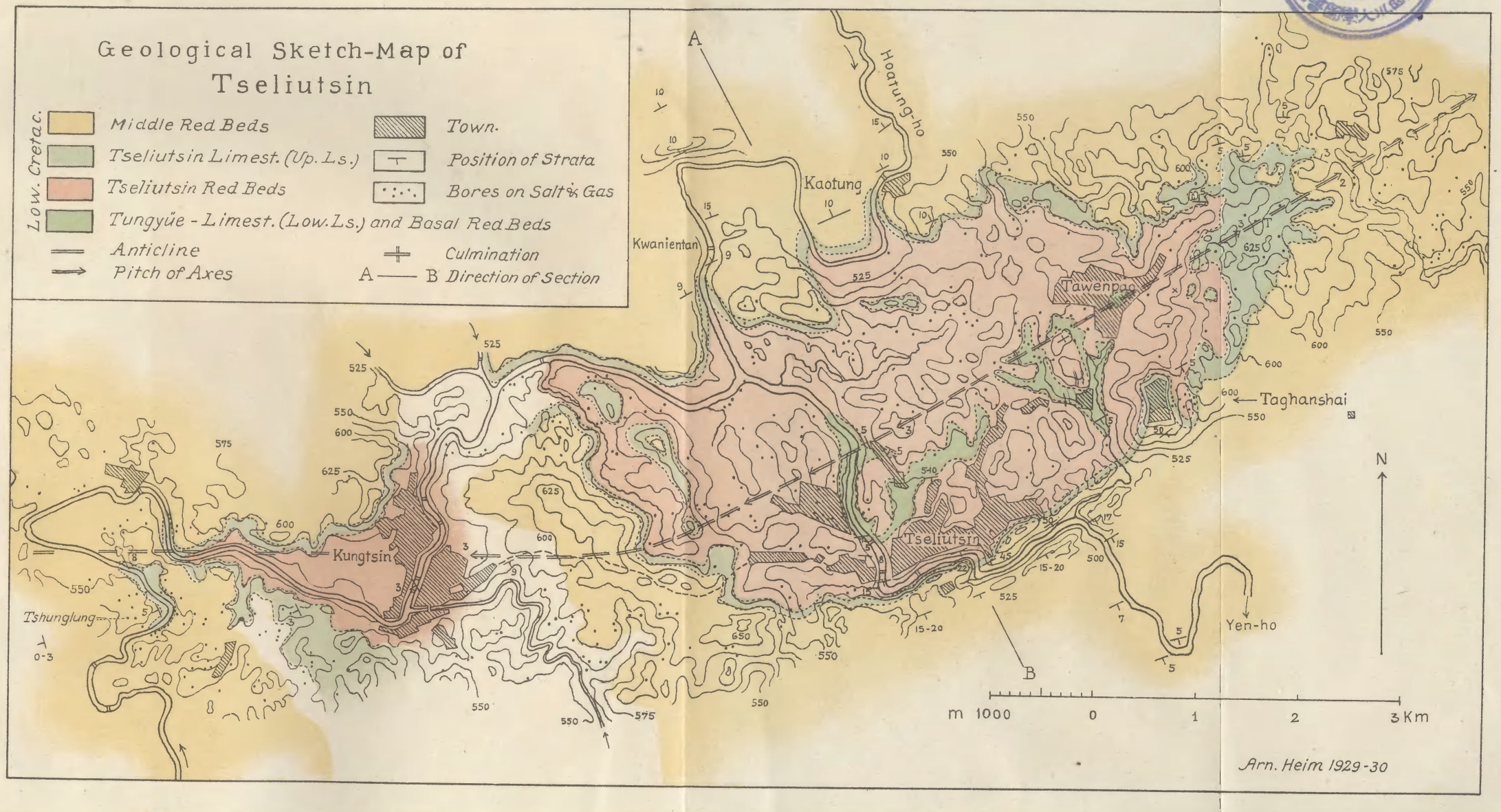


PLATE III.

Fig. 1. Tseliutsin, looking down on the Yenho, from the Salt Inspector's Residence towards N.E. After having cut across the Tseliutsin Limestone below the temple, the river turns to an isoclinal valley, with the sandstone of Tshungking Series dipping 40-55° S.S.E.

On the mountain in the background is the walled town Taghanshai (Compare Pl. IX, Fig. 2). For details compare Pl. IV, Fig. 1, Phot. A. H. 6.x. 1929.

Fig. 2. Bridge West of the town of Tseliutsin, looking east. In background school houses of Canadian Mission, in foreground at right Tungyüe Limestone full of fresh water pelecypods, especially large Unio. Phot. A. H. 6.x. 1929.

Fig. 3. Sandstone of Tseliutsin Red Beds (below Tseliutsin Limestone, nearly horizontal, dip 3° S.W., forming cataract of Yenho between the two bridges of Kungtsin, looking S.W. Phot. A. H. 8.x. 1929. a.m.

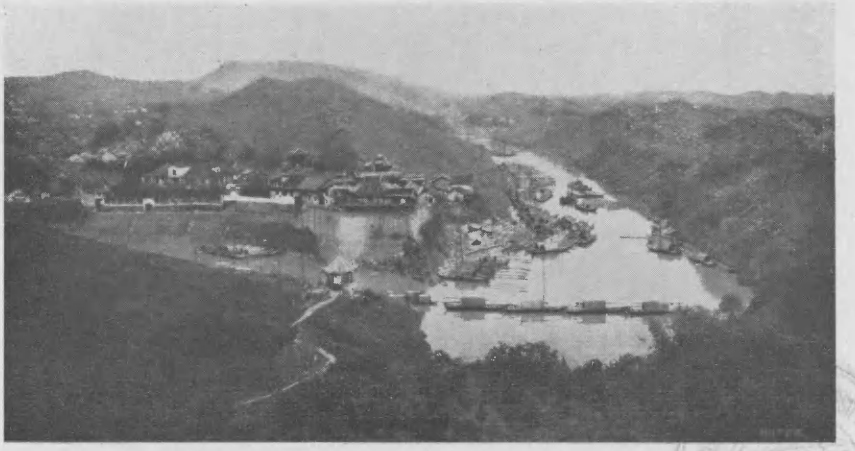


Fig. 1.

Fig. 2.

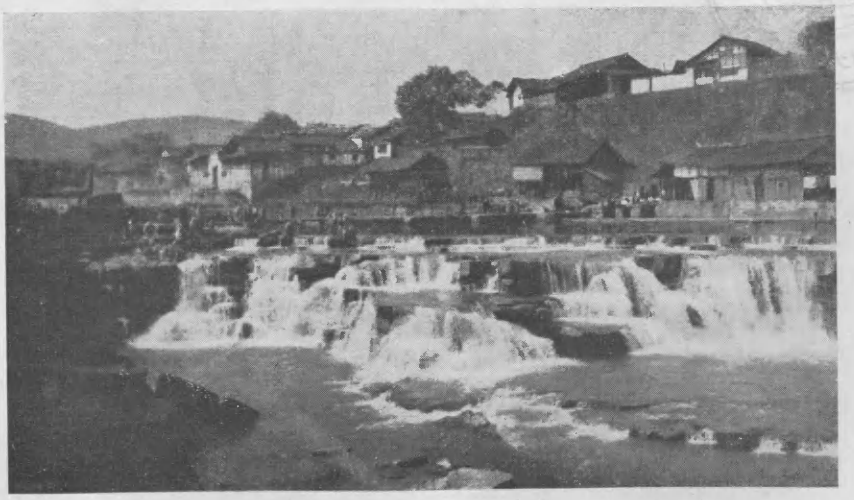


Fig. 3.

PLATE IV.

Fig. 1. Salt Commissioner office and temple on E. side of Tseliutsin, showing bend of Yenho with the Tseliutsin Limestone dipping 45° to S. 25° E. Compare with Pl. III, Fig. 1, Phot. A. H. 6.x. 1929.

Fig. 2. Salt wells in operation 15 km. W. of Tseliutsin (Fumindjing). In background the hills formed of the Tseliutsin Limestone, N. limb of anticline, looking N.N.E. Phot. A. H. 7.x. 1929.

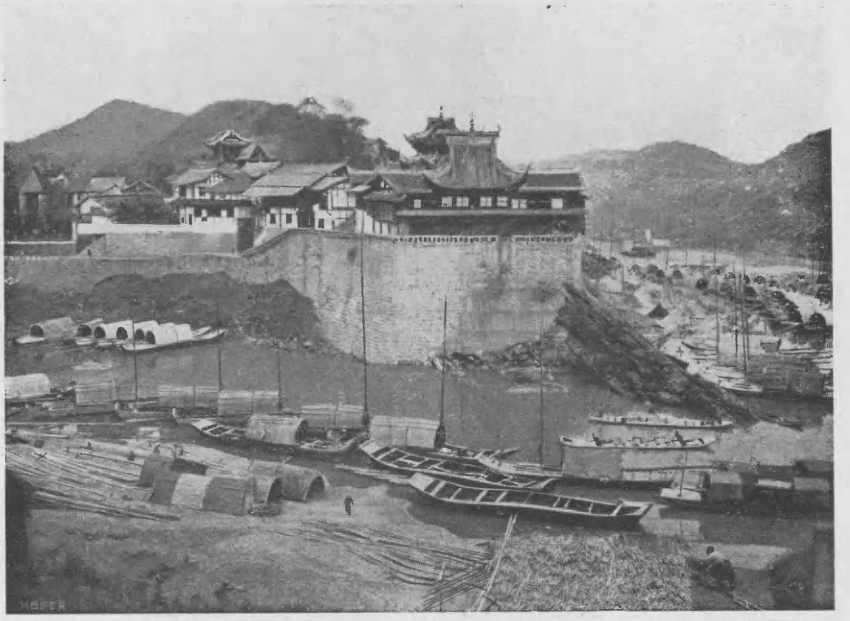


Fig. 1.

Fig. 2.

PLATE V.

Fig. 1. Salt-gasfield 2.5 km. west of Kungtsin, looking N.N.E. Deep wells over 3,000 ft., partly highly productive and rich in gas, partly drilling in the old fashion. Phot. A. H. 8.x. 1929.

Fig. 2. Borefield of Tawenpao (Dawenbao) 2-3 km. N.E. of Tseliutsin, on culminating part of anticline. Enormous derricks as high as those of California. Some steam engines introduced. Phot. A. H. 10.x. 1929.

Fig. 1.

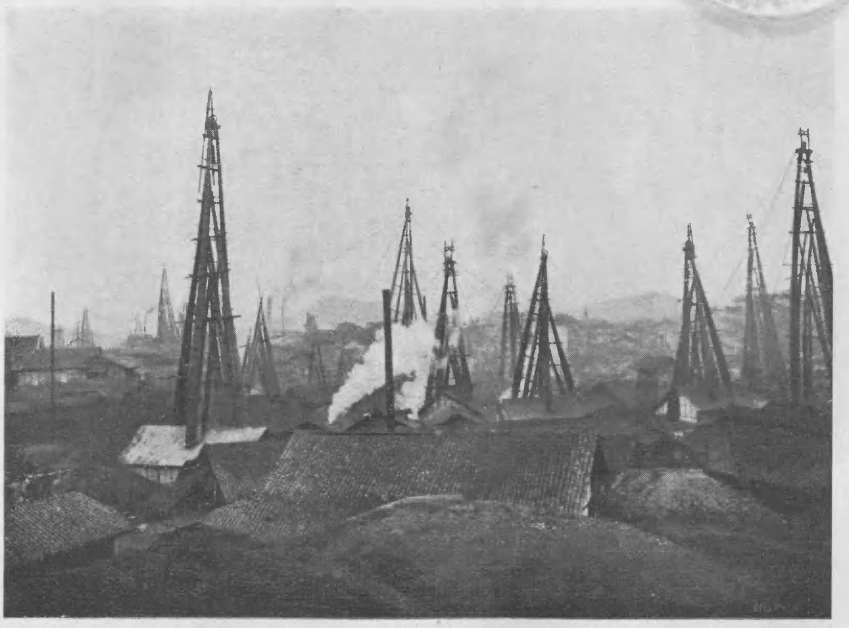


Fig. 2.

PLATE VI.

Fig. 1. Derrick passing roof of machine house. See size of poles compared with boy on roof.

Region W. of Kungtsin. Phot. A. H. 8.x. 1929.

Fig. 2. Old fashion drilling, six men stepping over the walking beam, one man handling the bit which is fastened on the bamboo rope. Tawenpao. Phot. A. H. 10.x. 1929.

Fig. 1.

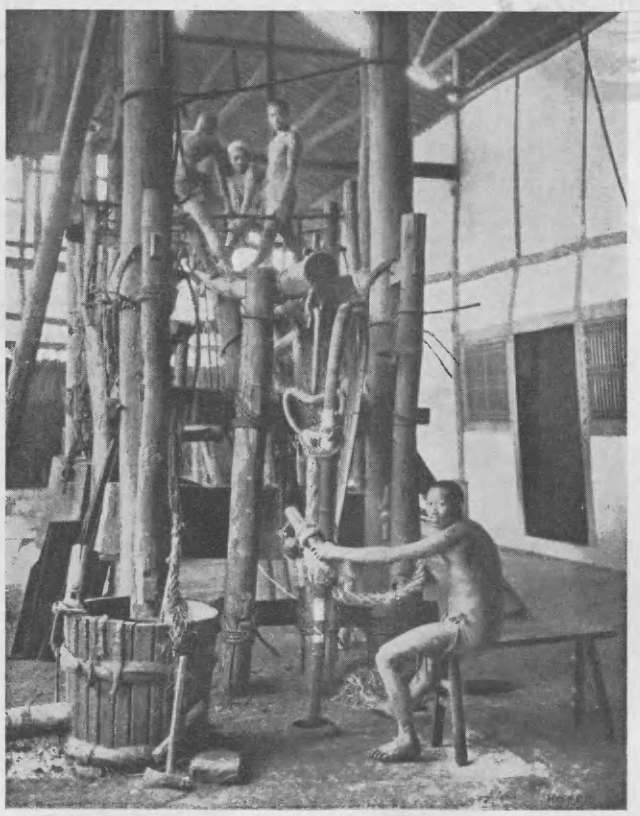


Fig. 2.

PLATE VII.

Fig. 1. Pumping the brine over the hills, step by step, with "leg-motor" of naked men, Tawenpao. Phot. A. H. 10.x. 1929.

Fig. 2. Same, looking backward to the valley. Phot. A. H. 10.x. 1929.

Fig. 1.

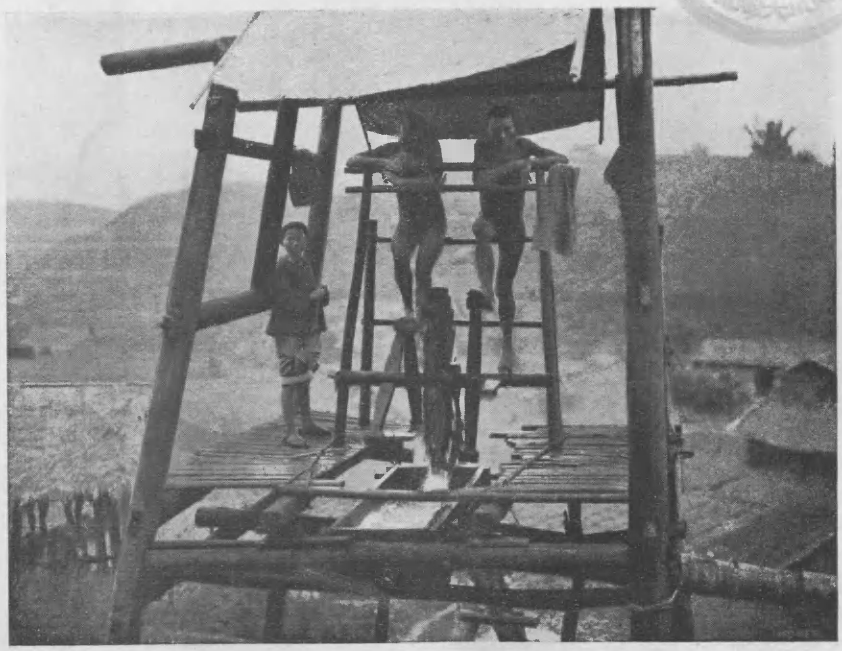


Fig. 2.

PLATE VIII.

Fig. 1. Pipe lines of bamboo for brine and gas. Kungtsin. Phot. A. H. 8.x. 1929.

Fig. 2. Boiling plant at Kungtsin W. (Tshunglung), 64 iron pans of brine being evaporated with the gas from one well. Phot. A. H. 8.x. 1929.

Fig. 1.

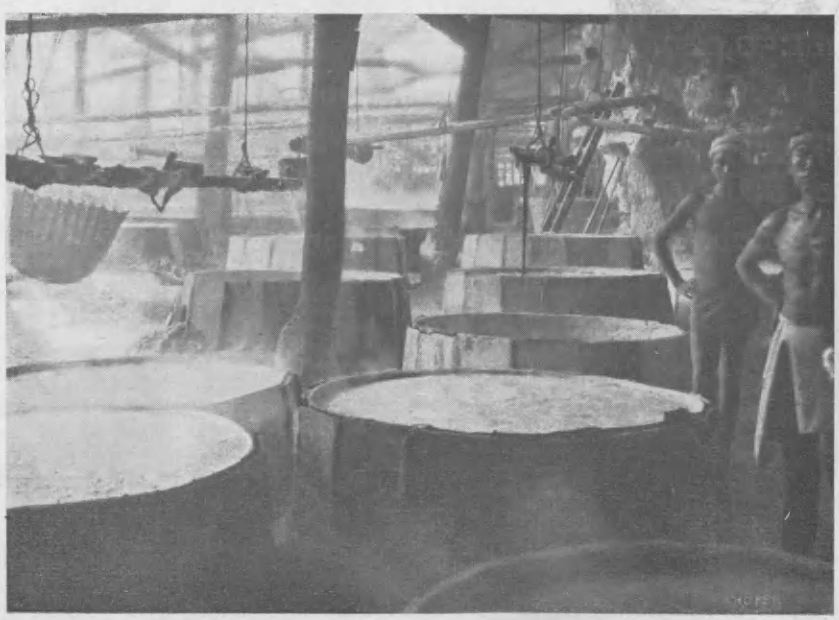


Fig. 2.

PLATE IX.

Fig. 1. Generalized section (1:65,000) across Tseliutsin-Anticline.

c = coal seams, s = salt, brine, g = gas.

Strata No. 1-10 below correspond to Fig. 2 and text. Upper numbers indicate angle of dip in degrees.

Tja-shön after verbal communication by Y. T. Chao.

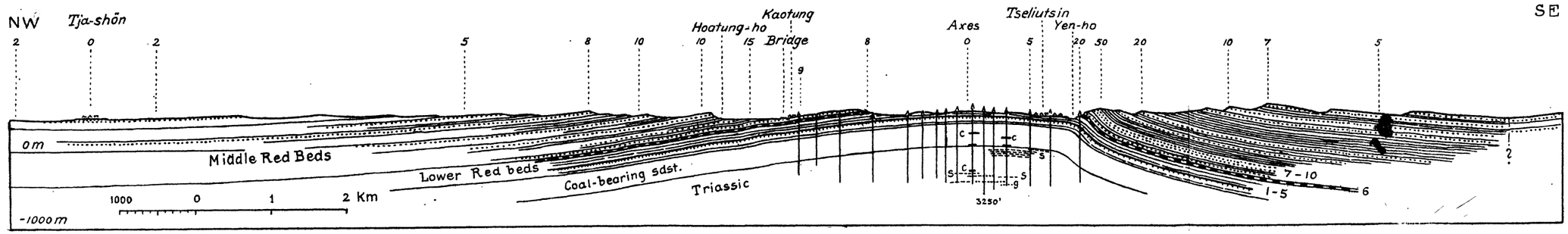
Fig. 2. Section across culmination of Tseliutsin Anticline, about 1:17,500.

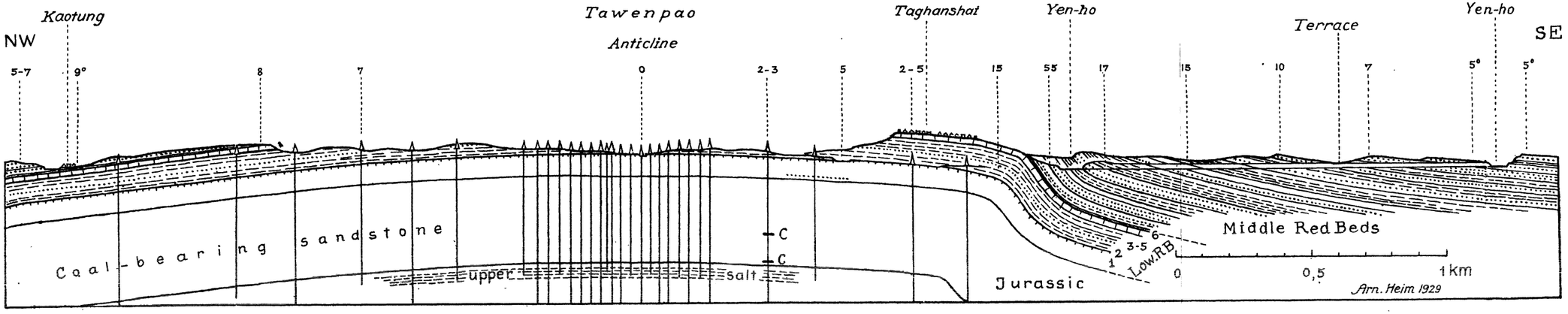
Same significations as Fig. 1. The bores are indicated schematically, their depths being partly unknown. The locations of those indicated, however, are correct.

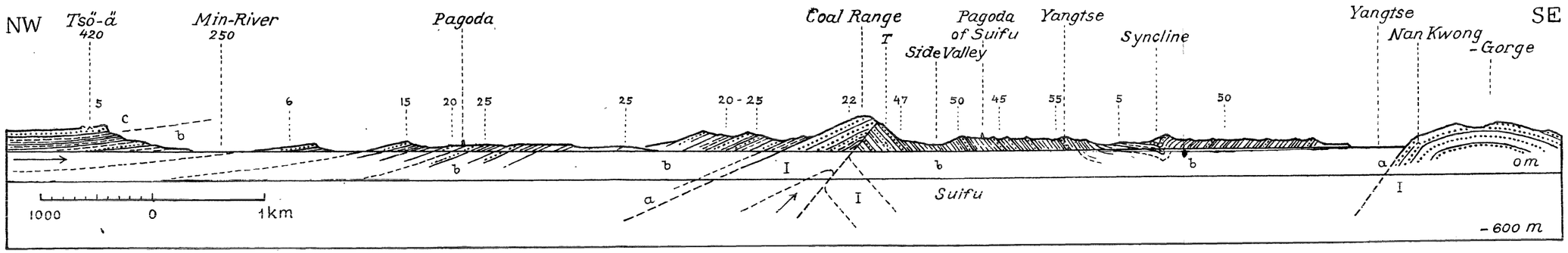
Fig. 3. Section along Min and Yangtse River at Süifu, about 1:50,000.

I = Coal-bearing sandstone, Jurassic: (a) Lower Red Beds, (b) Middle Red Beds (Tshungking Series), (c) Upper Red Beds, Kiating Series.

Numbers above: dip of strata in degrees.


NW
Tja-shön
Hoatung-ho
Kaotung
Bridge
Axes
Tseliutsin
Yen-ho
SE
0m
Middle Red Beds
Lower Red beds
Coal-bearing sdst.
Triassic
1000 0 1 2 Km
-1000m
3250'
7-10
1-5
6


NW
Kaotung
Tawenpao
Anticline
Taghanshai
Yen-ho
Terrace
Yen-ho
SE
Caal-bearing sandstone
upper salt
C
C
Jurassic
Low.RB
Middle Red Beds
0 0,5 1km
Arn. Heim 1929


NW
Tsö-ä
420
Min-River
250
Pagoda
Coal Range
Pagoda
of Suifu
Side Valley
Yangtse
Syncline
Yangtse
Nan Kwong
-Gorge
SE
1000 0 1km
Suifu
om
- 600 m

封　底